Royal Norwegian Council for Scientific and Industrial Research

● DATA
CENTER

OSLO ●

AD 757204

NORWEGIAN SEISMIC ARRAY

NORSAR

ESD-TR-73-123

NTNF/NORSAR
P.O. Box 51
N-2007 Kjeller
NORWAY

NORSAR REPORT No. 49

EVENT DETECTION AND
LOCATION CAPABILITIES
AT NORSAR

by

H. Bungum

29 December 1972

This report has been reviewed and is approved.

Richard A Jedlicka, Capt USAF
Technical Project Officer
Oslo Field Office
ESD Detachment 9 (Europe)

ARPA Order No. 800   Program Code No. IF10

Name of Contractor   :   Royal Norwegian Council
                                      for Scientific and
                                      Industrial Research

Date of Contract   :   15 May 1970

Amount of Contract   : $2,051,886

Contract No.   :   F19628-70-C-0283

Contract Termination Date   :   30 June 1973

Project Supervisor   :   Robert Major, NTNF

Project Manager   :   Nils Marås

Title of Contract   :   Norwegian Seismic Array
                                      (NORSAR)

ABSTRACT

Data published in the NORSAR seismic bulletin between
February and June 1972 has been studied in order to
find estimates of the detectability and location
accuracy at NORSAR. The detectability is calculated
from empirical frequency-magnitude distributions,
and the 90% cumulative detectability for the tele-
seismic zone ($30^{\circ} < \Delta < 90^{\circ}$) has been estimated at $m_b 4.0$,
while values for different regions vary from 3.7
to 4.3. These are all NORSAR magnitudes. The
magnitude bias between NOAA and NORSAR has been
found to be 0.15±0.31 in the teleseismic zone. In
this zone, the median location difference between
NOAA and NORSAR has been estimated at 160 km, with
values for different regions ranging from 130 to
340 km.

INTRODUCTION

The Norwegian Seismic Array came into full operation in
the first months of 1971. The array, including the routine
data processing, is described in detail by Bungum et al
(1971). Fig. 1 shows the essential parts of the data
processing system at NORSAR. The Detection Processor
first takes care of the recording of all data on
magnetic tapes. Then, the NORSAR SP data is processed
in real time in search of seismic events, and a queue of
detections is created. Some of these detections are
later selected for further analysis by the off-line Event
Processor, which produces an automatic seismic bulletin.
This bulletin is reviewed daily by analysts, and changes
are often made before the bulletin can be distributed.

Since 1 May 1971 a reviewed seismic bulletin has been
created on a daily basis at NORSAR. This paper is con-
cerned with an evaluation of the data presented in that
bulletin, and will be concentrated on the ability of the

Data from NORSAR

132 SP instruments
66 LP instruments

Det.
Log
Tape

LP
Data
Tape

Detection
Processor

Transatlantic
Data Link
SAAC (LASA)

SP
Data
Tape

Detection
Queue

Event
Processor

Event
Tape
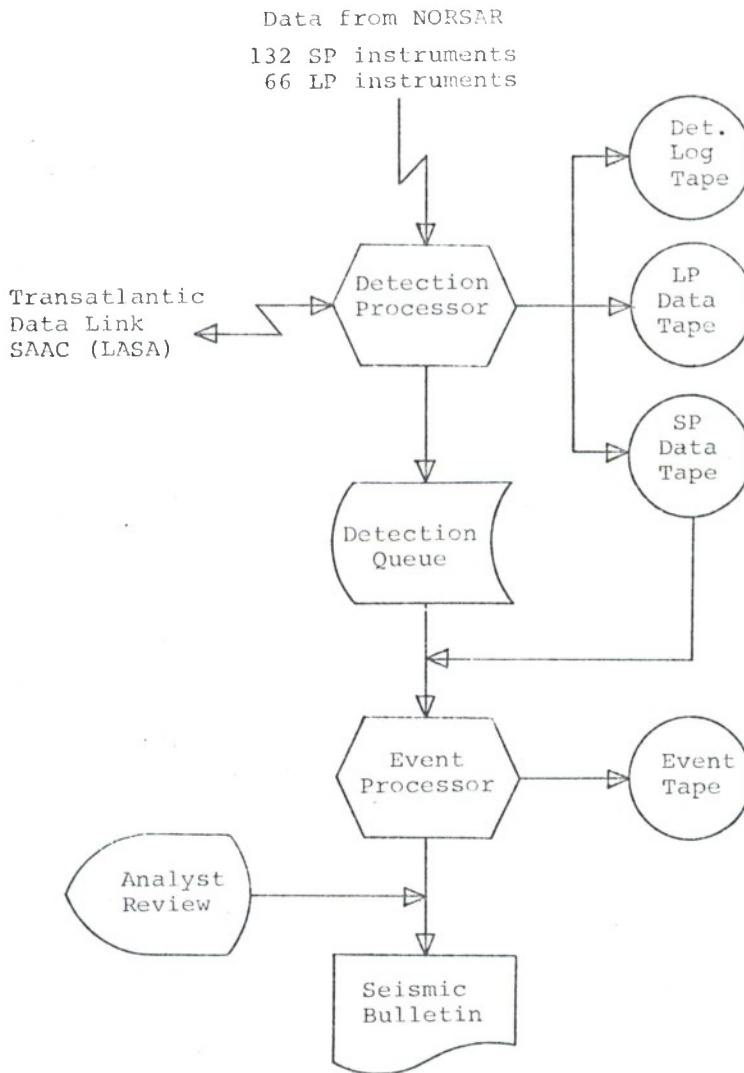
Analyst
Review

Seismic
Bulletin

Fig. 1   Schematic view of the NORSAR data processing
          system.

array to detect and locate seismic events, estimated
through a statistical analysis of the data in the
seismic bulletin.

DETECTABILITY

Detectability as used in this paper can be defined as
the long term operational ability to report, with epi-
central information, the occurrence of seismic events.
The term detectability is therefore used mainly for
notational convenience.

Work continues steadily in order to improve the per-
formance of the array. A number of changes have sig-
nificantly improved both the detectability and the location
accuracy. The main changes are: (1) improved analyst per-
formance, (2) a new array beam deployment as of 14 Dec 1971,
(3) on-line filter change from 0.9-3.5 Hz to 1.2-3.2 Hz
as of 6 Jan 1972, and (4) new time delay and location cor-
rections as of 27 Jan 1972. The effect of these changes
on the detectability can be seen in Table 1, which shows
the monthly number of events reported by NORSAR for the
time period May 1971 - October 1972. Also given is the
number of events reported by NOAA and the number reported
by both institutions. The number of reported events is,
of course, also dependent upon other factors, first of
all time variations in seismicity and long term varia-
tions of the noise level.

One of the aims in the analysis work has been to keep the
false alarm rate in the seismic bulletin at a low level.
This is not possible unless a large number of true detec-
tions are left unreported. Some of these could have been
included by devoting more time and effort to the analysis,
and some could probably be confirmed through a study of
the bulletins from other networks.

NUMBER OF EVENTS

Month	NORSAR	NOAA	Common
1971			
May	230	330	122
Jun	264	277	113
Jul	415	591	184
Aug	320	387	136
Sep	334	359	161
Oct	244	381	150
Nov	154	289	90
Dec	280	368	175
1972			
Jan	283	393	168
Feb	379	393	215
Mar	424	354	187
Apr	605	348	225
May	505	395	163
Jun	470		
Jul	547		
Aug	605		
Sep	742		
Oct	496		

TABLE 1

Number of events reported by NORSAR, NOAA and by the two
institutions in common.

The number of events N above a given magnitude m,
within a certain time period, is generally assumed to
follow the relationship

$$\log N = A - b \cdot m$$

both for the entire world and for more limited geographi-
cal regions. On this assumption, empirical frequency-
magnitude distributions would then make it possible to
determine the parameters A and b. Fig. 2 shows such
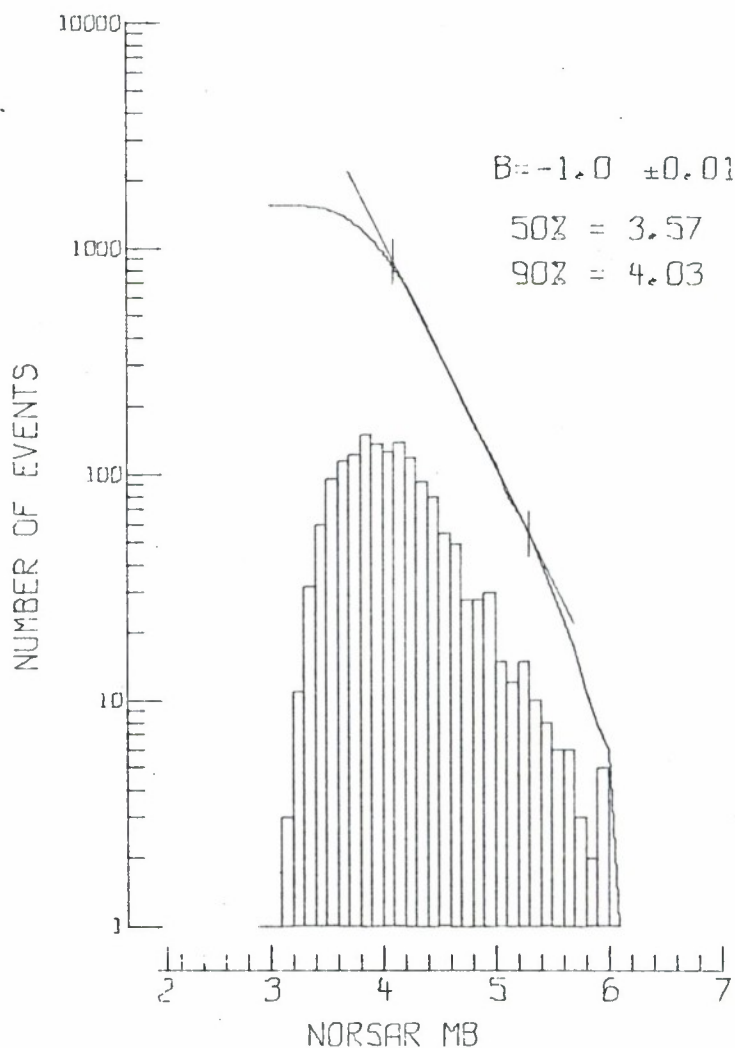a distribution, both incremental and cumulative, for the

Fig. 2   Interval and cumulative frequency-magnitude distribution
for data from Feb-Jun 1972, range 30-90 deg. Straight
line is a least squares fit through data within bars.

NORSAR teleseismic zone ($30^O<\Delta<90^O$). The slope has
been estimated by fitting a straight line, in a least
squares sense, through the straight part of the cumula-
tive frequency-magnitude curve. Then, the 50% and 90%
levels for detectability are determined, based on com-
putation of the assumed number of missed events at any
particular magnitude. As Fig. 2 shows, the NORSAR tele-
seismic data from Feb-June 1972 has a slope of b = 1.00
± 0.01, and the 50% and 90% detectability levels are
m_b 3.6 and 4.0 respectively.

It is important to point out that the magnitudes which
are quoted above are all NORSAR estimates. In order
to facilitate comparisons with other networks, the rela-
tion between NORSAR and NOAA magnitudes has also been
investigated. Another point worth noticing is that by
presenting data from the entire teleseismic zone, one
is combining data with possible different statistical
distributions. Therefore, all the results are also
presented regionalized, where the regions are defined
in distance and azimuth from NORSAR, as given in Table 2.

Region		Regional limits (deg)		Magnitude threshold			Magnitude bias		Location difference		
No	Name	Azimuth	Distance	Events	50%	90%	Events	NOAA-NORSAR	Events	50%	90%
A		0-360	30-90	1555	3.6	4.0	848	0.15±0.31	509	160	510
A1	Atlantic	180-260	30-90	88	3.6	4.3	13	0.45±0.28	11	340	780
A2	N. America	260-340	40-90	114	3.8	4.2	100	0.20±0.33	61	260	810
A3	Aleutians	340-15	30-90	131	3.4	3.9	119	0.17±0.35	57	150	370
A4	Japan	15-70	50-90	738	3.7	4.1	441	0.10±0.29	271	130	530
A5	C. Asia	40-110	30-60	211	3.2	3.7	89	0.20±0.34	43	130	270
A6	Iran	110-180	30-90	262	3.5	3.8	39	0.23±0.29	53	180	520

TABLE 2

Regionalized results for magnitude thresholds (NORSAR m_b), NOAA/
NORSAR magnitude bias and NOAA/NORSAR location differences. The
data for magnitude thresholds is from Feb-June 1972, except for
region A1 with data from May 71-June 72. The data for magnitude
bias is all from May 71-June 72, while the data for location
differences is from Feb-May 72.

The regionalized results for the magnitude thresholds are all listed in Table 2. As one can see, the 90% detectability level is m_b 4.0 when all teleseismic data is used, while the values for different regions vary from 3.7 in Central Asia to 4.3 on the Mid-Atlantic Ridge. As mentioned above, this cannot be fully evaluated before the possible magnitude bias between NORSAR and some known reference, say NOAA, has been investigated. Fig. 3 shows the NOAA/ NORSAR magnitude difference as a function of epicentral
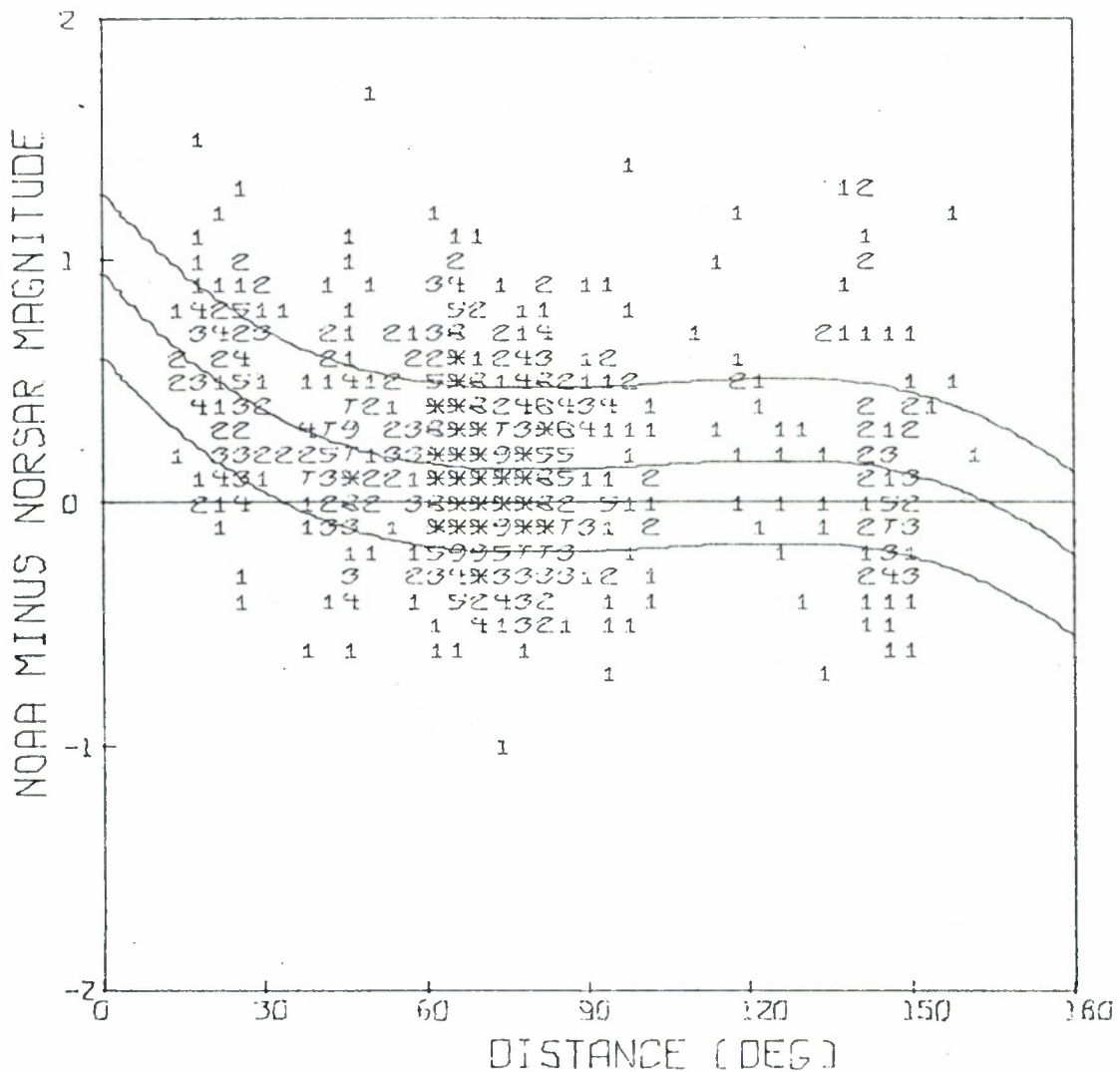
Fig. 3 NOAA/NORSAR magnitude differences vs. epicentral distance for data from May 71–March 72. The curves represent a third degree least squares fit through data, with upper and lower bounds (STD).

distance, where a clear negative bias in the NORSAR
data is observed for epicentral distances smaller than
30°. A likely explanation of that bias is the fact
that magnitude is measured on the array beam, and more
local events have, due to poor coherence across the
array, a significant beamforming loss which is not com-
pensated for in the magnitude calculation. As Fig. 3
shows, the scatter in the magnitude data is quite large.
Table 2, which gives all the detailed results also for
the magnitude bias, shows a bias of 0.15 ± 0.31 for
all data within $30^{\circ}-90^{\circ}$, while the different regions
have values ranging from 0.10 in Japan to 0.45 on
the Mid-Atlantic Ridge. The scatter in the data is
approximately of the same size for all regions.

Now, if one should express the NORSAR magnitude thresholds
in terms of some "NOAA equivalent magnitude", one would
have to add the bias to the threshold values in Table 2.
By doing so, one would get a 90% level of m_b 4.2 for
all data within the teleseismic zone, with values for
different regions ranging from 3.9 in Central Asia to
4.7 on the Mid-Atlantic Ridge.

It is important to keep in mind when reading Table 2
the special definition of detectability given above.
There could easily be a significant difference between
the operational and the optimum ability to detect and
report events. Another factor of significance is
that some of the regions presented in Table 2 so far
have not very much data. The regional differences are,
however, so large that the trends are quite clear.

One should also notice that the data presented herein
is mainly from a time of year when the background noise
level is moderate. The noisiest time period so far has

been October-December 1971, a period which also shows
a minimum in the number of reported events (Table 1).
This has been found from an extensive study of the
long term short period noise level within the on-line
processing frequency band. For the time period January-
May 1972, the median noise level within the frequency
band 1.2-3.2 Hz has been found to be 1.15 mµ. Some
uncertainties apply to the ground motion conversion in
this case, while the estimates for the relative varia-
tions are more accurate. The 90% level is 2.0 dB
above the median and the 10% level is 2.7 dB below,
and the long term average can be well approximated
by a Gaussian distribution.

LOCATION DIFFERENCES

The location differences between NORSAR and NOAA have
also been studied. Since new location corrections were
implemented in January 1972, only four months of data
were available for investigation. Fig. 4 shows the
location differences within the teleseismic zone, in-
cremental and cumulative. From curves like that, the
50% and 90% levels of location differences have been
found, and the detailed regionalization results are
also given in Table 2. The teleseismic zone shows a
median location difference of 160 km, while Japan and
Central Asia as the best regions have 130 km and North
America as the poorest has 340 km. The expression
location difference (and not location error) has been
used because the comparison is made between two esti-
mates which both are affected by uncertainties. Since
the NOAA standard error of location is in the range
of 10-40 km, this clearly becomes significant for re-
gions where Table 2 shows a location difference of
about 120 km, as for Japan.
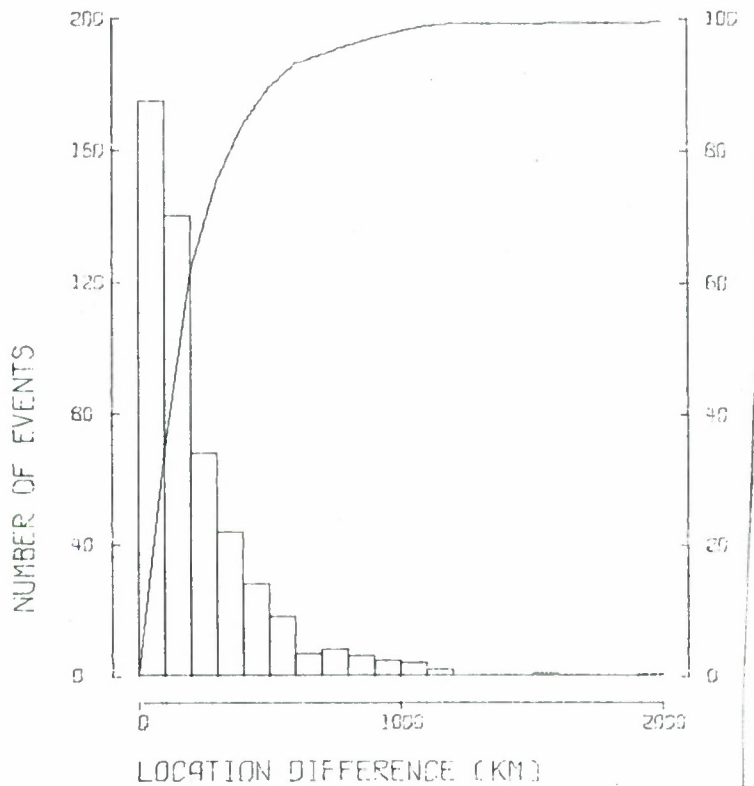
Fig. 4   Interval and cumulative distribution of location
         differences between NOAA and NORSAR for data from
         Feb-May 1972, range 30-90 deg.

The regionalized results for the location differences
would also here have some uncertainties caused by
the limited amount of data.   Another factor worth men-
tioning is that the comparison is made only for events
above the NOAA reporting threshold, which for some
regions is significantly higher than the NORSAR threshold.
One should expect that the location error for small events
on an average is somewhat larger, but not much, since the
error in most cases would still be within the beam radius,
typically 2-3 degrees.

REFERENCES

Bungum, H., E.S. Husebye and F. Ringdal: The NORSAR
Array and Preliminary Results of Data Analysis, Geophys.
J.R. Astr. Soc., Vol 25, 115-126, 1971.

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*	2a. REPORT SECURITY CLASSIFICATION
Royal Norwegian Council for Scientific & Industrial Research P. O. Box 51 N-2007 Kjeller, NORWAY	UNCLASSIFIED
	2b. GROUP — N/A

3. REPORT TITLE

EVENT DETECTION AND LOCATION CAPABILITIES AT NORSAR

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

None

5. AUTHOR(S) *(First name, middle initial, last name)*

H. Bungum

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
29 December 1972		

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
F19628-70-C-0283	ESD-TR-73-123
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	NORSAR Report No. 49

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Deputy for Planning and Technology Hq Electronic Systems Division (AFSC) L G Hanscom Field, Bedford, MA 01730

13. ABSTRACT

Data published in the NORSAR seismic bulletin between February and June 1972 has been studied in order to find estimates of the detectability and location accuracy at NORSAR. The detectability is calculated from empirical frequency-magnitude distributions, and the 90% cumulative detectability for the teleseismic zone ($30° < \Delta < 90°$) has been estimated at $m_b 4.0$, while values for different regions vary from 3.7 to 4.3. Theses are all NORSAR magnitudes. The magnitude bias between NOAA and NORSAR has been found to be 0.15 ± 0.31 in the teleseismic zone. In this zone, the median location difference between NOAA and NORSAR has been estimated at 160 km, with values for different regions ranging from 130 to 340 km.

DD FORM 1 NOV 65 **1473**

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT